

# Architecture of LOW

# Energy 低能耗建筑 Consumption

凤凰空间·上海 编



江苏人民出版社

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策划编辑: 张晓华 毛玲玲 王培娟 石莹

责任编辑: 刘焱 张晓华 毛玲玲

责任监印: 彭李君

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# ARCHITECTURE OF LOW ENERGY CONSUMPTION

## 低能耗建筑

凤凰空间·上海 编

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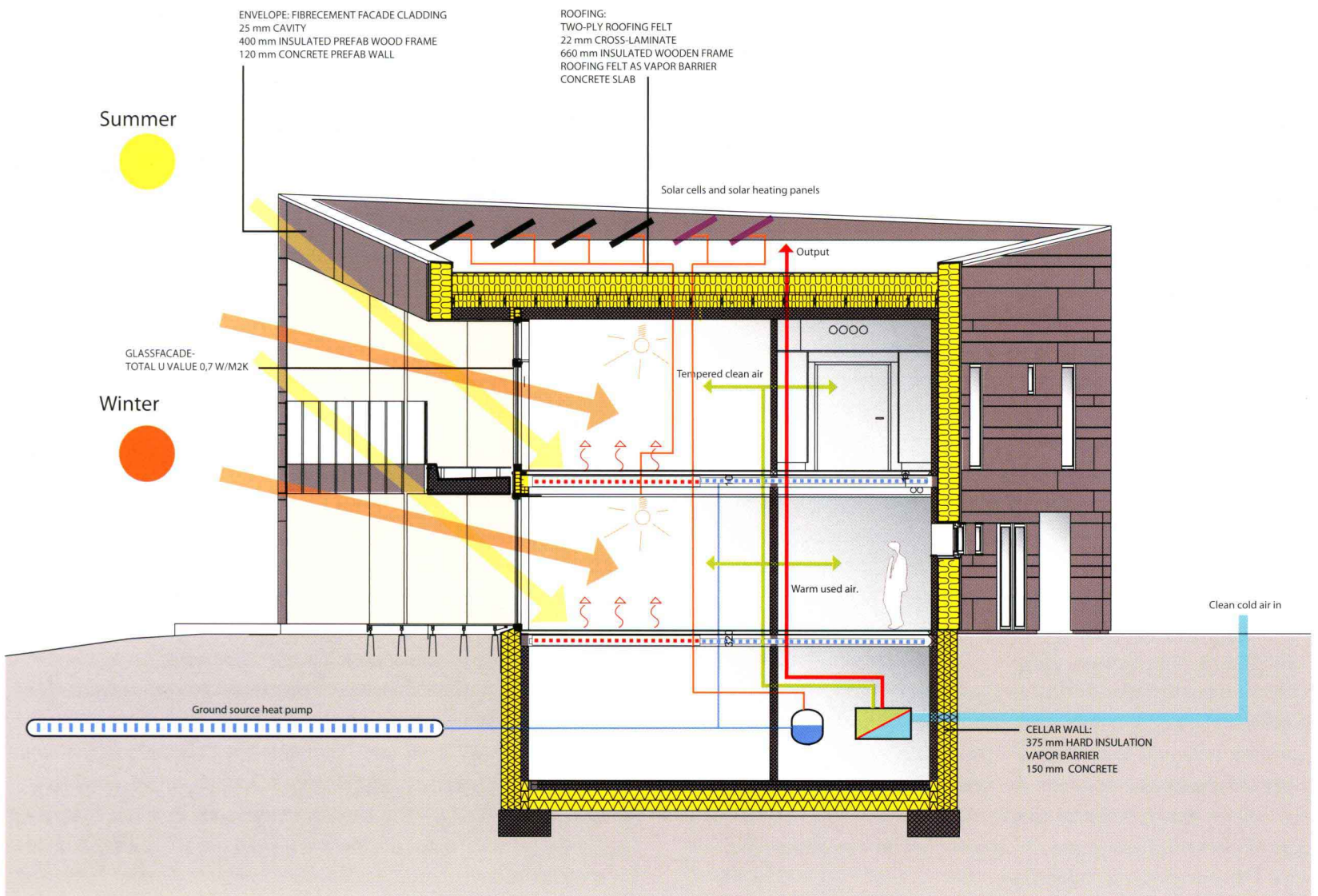


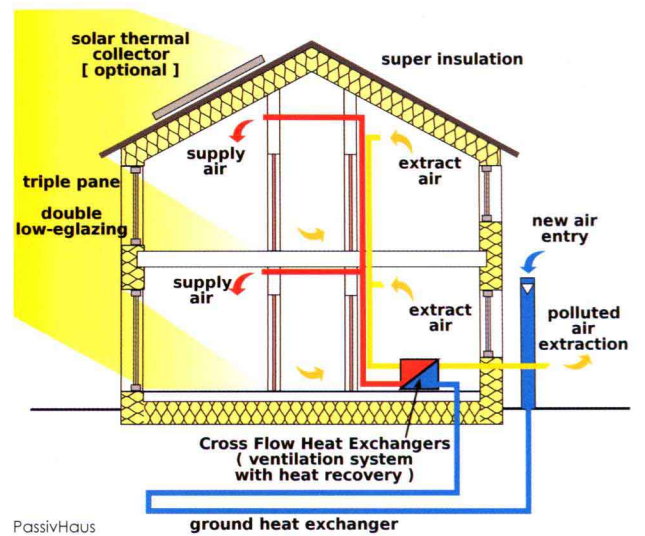
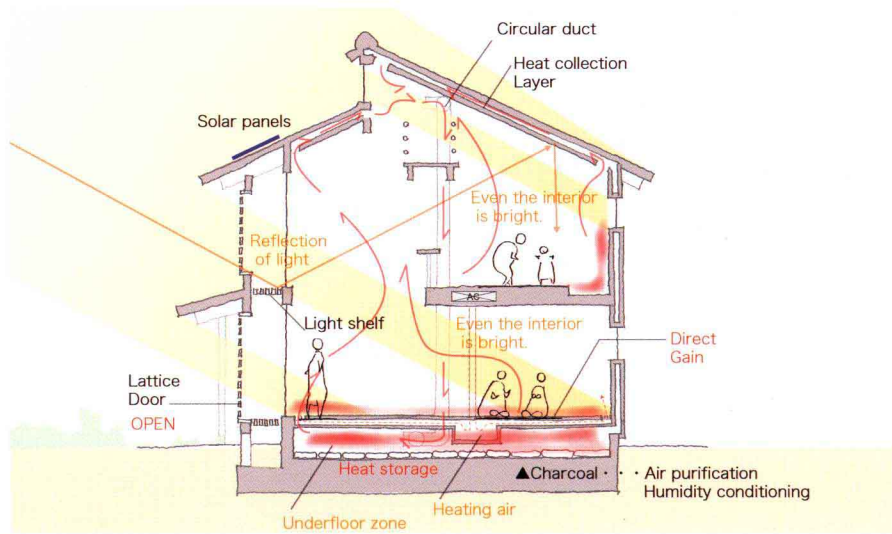
# 综述

As an energy-consuming sector, the building industry has great energy-saving potential. Centering on the energy conservation of buildings, in this part we will present a comprehensive introduction to the definition and national reference standards of low-energy building as well as energy-saving technologies.

建筑业作为高能耗产业，具有巨大的节能潜力。本节将围绕建筑节能这一话题展开，对低能耗建筑的概念，部分国家的低能耗建筑参考标准以及节能技术等方面的知识进行综合性的阐述。

# OVERVIEW





## 1 Definition of Low-energy Building 低能耗建筑的定义

A low-energy building is any type of building that from design, technologies and building products uses less energy, from any source, than a traditional or average contemporary building. Low energy buildings are designed to provide a significantly higher standard of energy efficiency than the minimum required by national building standards.

Specifically, the definition of low energy building varies significantly across the world. The variation exists not only in terms of the absolute possible level of energy consumption, but also the calculation methods and the energy flows included in the requirements, etc.

Most official calculation methods cover buildings' primary energy consumption. Nonetheless, how the corresponding energy demand is converted into primary energy differs from country to country. Further, in some cases the primary energy consumption is converted into CO<sub>2</sub> emission. The definition and consequently the calculation of primary energy consumption is strongly dependant on the chosen boundary for calculation. Accordingly, the definition of low-energy building varies greatly from country to country.

对于任何一种类型的建筑，如果在设计、技术应用以及建筑产品的使用等各方面的能量消耗低于传统建筑或者现代建筑的一般水平，我们称之为“低能耗建筑”。低能耗建筑的能源利用效率通常高于各国的建筑标准的规定。

确切地说，世界上的各个国家和地区对低能耗建筑的定义是不尽相同的。这些差异不仅体现在能量消耗的绝对值水平上，更体现在各国采用的能耗计算方式以及计算所涵盖的能量流之中。

大部分的官方计算方式针对的都是建筑的初级能源消耗。然而，在不同的国家，将相应的能源转化为初级能源的方式与过程又是不一样的，并且，在某些情况下还会用初级能源消耗转换成二氧化碳的排放量来进行计算。因此，初级能源消耗的界定以及计算在很大程度上取决于计算标准，相应地，各国对低能耗建筑的定义也就有所不同。

## 2 Standards of Low-energy Building & Energy Rating Systems 低能耗建筑标准和能耗等级评估体系

In some countries, the term relates to a specific building standard. In particular they seek to limit the energy used for space heating since in many climate zones it represents the largest energy use. But other energy use may also be regulated. Because national standards vary considerably around the world, "low-energy" developments in one country may not meet "normal practice" in another.

在部分国家，低能耗建筑具有特定的参考标准。由于在许多气候带，空间供暖占据了最大部分的能量消耗，各国的标准主要是限制这方面的能耗，但是其他方面的能量消耗也有可能涉及到。同时，由于低能耗建筑标准在世界各地存在着很大差异，某个国家的低能耗建筑在另一个国家有可能就不符合要求。

### (1) Germany – Niedrigenergiehaus & PassivHaus 德国低能耗建筑标准与被动房标准

In Germany a low-energy house (Niedrigenergiehaus) has a limit equivalent to 7 liters of heating oil for each square meter of room for space heating annually (50 kWh/m<sup>2</sup>/yr or 15,850 Btu/ft<sup>2</sup>/yr).

In comparison, the German PassivHaus ultra-low-energy standard has a maximum space heating requirement of 15 kWh/m<sup>2</sup>/yr or 4,755 Btu/ft<sup>2</sup>/yr.

PassivHaus is a leading international low energy design standard. The term PassivHaus refers to a voluntary, low energy construction standard, first developed by Dr Wolfgang Feist of the PassivHaus Institut in Germany. Buildings of this construction standard have been built mainly in Germany but also in Austria, Switzerland, USA and more recently in the UK.

The PassivHaus design standard is integrated with the architectural design and although it has generally been used for new buildings, it has also been used for refurbishment projects. A building can be certified as a PassivHaus when the following criteria are met:

- The building must not use more than 15 kWh/m<sup>2</sup>/yr in heating energy.
- The standard requires very precise levels of insulation for every construction element. Every external surface must have a U-value lower than 0.15 W/m<sup>2</sup> K and there are tight restrictions on the relative window surface.
- The total use of primary energy (e.g. fuels) for all uses combined (heating, hot water and specifically electricity) may not exceed 120 kWh/m<sup>2</sup>/yr.
- With the building depressurised to 50 Pa (N/m<sup>2</sup>) below atmospheric pressure using an approved air leakage testing method, the building must not leak more air than 0.6 times the house volume per hour.

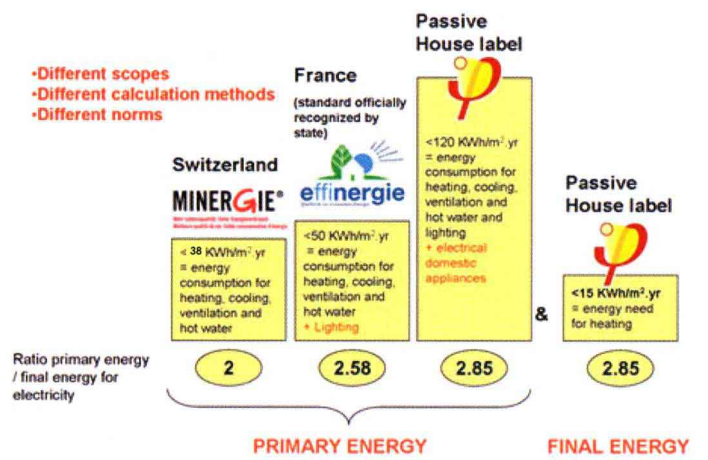
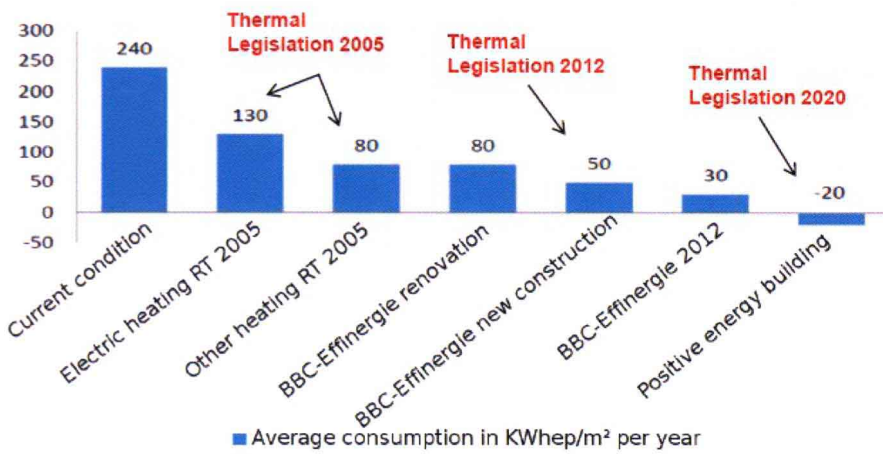
Originally developed in Germany for houses and low-rise multi-unit residential buildings, the standard has been applied to houses in a range of other countries and to office buildings, schools, and commercial buildings as well.

在德国，按照Niedrigenergiehaus标准的规定，低能耗建筑的空间供暖能耗标准是50 kWh/m<sup>2</sup>/yr (15,850 Btu/ft<sup>2</sup>/yr)，也就是指房间的每平方米的空间供暖能耗应该不高于7升取暖油。

相对而言，德国的被动房标准PassivHaus则提出了更高标准的低能耗设计，按照其规定，最大的空间供暖能耗应为15 kWh/m<sup>2</sup>/yr (4,755 Btu/ft<sup>2</sup>/yr)。

PassivHaus目前已经成为了国际上最主要的低能耗设计标准。它是由德国被动式房屋研究所的沃尔夫冈·菲斯特提出的一项自发的低能耗建筑标准。该标准起初主要应用于德国的建筑设计，但如今奥地利、瑞士、美国，尤其是英国也有很多利用该





Effinergie

标准建造的房屋。

该标准与建筑设计相结合，虽然通常是用于新建筑的建造，但在既有建筑的装修中也有用到。符合PassivHaus标准的建筑必须满足下列条件：

- 建筑供暖能耗不得超过15 kWh/m²/yr。
- 建造元素必须达到特定的隔热水平，建筑外表面的U值必须低于0.15 W/m²K，而相关的窗户表面也有严格的限制值。
- 用于供暖、热水和供电的初级能源（如燃料）不得高于120 kWh/m²/yr。
- 使用气密性试验进行检测，将室内气压降至标准大气压下50帕的情况下，建筑每小时的气体渗透量不得超过建筑体积的0.6倍。

PassivHaus最初是德国制定的适用于住宅和低层公寓楼的标准，如今已经被其他许多国家采用，适用范围也从住宅扩展到办公楼、学校以及商业建筑。

## (2) France – Effinergie 法国低能耗建筑标准

The Effinergie Association was created in May 2006 to promote low energy buildings in France. Effinergie is a registered quality label for new and refurbished low-energy-consumption buildings in France. It is communicated in the sector under the name BBC-effinergie. BBC stands for "Bâtiment Basse Consommation" (Low Energy Building).

In order to obtain the BBC-effinergie label, the main requirement consists in not exceeding a consumption value of 50 kWhpe per m² of NFA per year. The diversity of climates is taken into account as this value of 50 is multiplied by a coefficient of climate harshness. As a consequence, the values of this requirement fluctuate according to the regions. The coefficient of climate harshness is increased by 0.1 if the construction altitude ranges from 400m to 800m and it is increased by 0.2 if the construction altitude is higher than 800m. Besides, the building's air tightness must be measured and be under 0.6 m³/h.m² for a detached house and under 1 m³/h.m² for apartment buildings.

The consumption – that should not be exceeded – applies to the energy utilizations that can be actively influenced from the design of a building, including heating, hot water, auxiliary appliances for ventilation and heating, lighting (via natural lighting) and air-conditioning. It does not include the other utilizations of electricity, particularly the household appliances, audiovisual equipment...

### New Buildings

- The global energy consumption in homes shall be less than 50 kWh/ m² /yr multiplied by a factor depending on the altitude and the climate zone, namely between 40 and 70 kWh/ m²/yr.
- The global energy consumption in tertiary buildings shall be 50% less than the level of RT (Thermal Regulation) 2005.

### Existing Buildings

- In homes, the global energy consumption shall be less than 80 kWh/ m²/yr.

-In tertiary buildings, the global energy consumption shall be 40% less than the level of RT 2005.

法国Effinergie协会成立于2006年5月，旨在促进低能耗建筑在法国的发展。Effinergie是一个已经注册的质量标识，针对的是法国的低能耗住宅，包括新建的和改造的。该标识通常被命名为BBC-effinergie，BBC是法语词“Bâtiment Basse Consommation”的缩写，意思是低能耗建筑。

要获得BBC-effinergie标识，建筑每年的能量消耗不得高于50 kWhpe/m²。这一标识制度考虑到了气候的多样性，具体到某一气候区的能耗标准时，会在该标准值的基础上乘以一个气候系数。因此，标准值会根据地域的不同而有所浮动。当建筑海拔在400米到800米之间时，气候系数会增加0.1，而海拔高于800米时，气候系数会增加0.2。另外，建筑的气密性也是必须考虑的一个要素，独立式住宅的漏气量必须低于0.6 m³/h.m²，而公寓楼的漏气量必须低于1 m³/h.m²。

在计算建筑所消耗的能量时，通常会考虑受建筑设计影响较大的方面，如供暖、热水、通风与供暖辅助设备、照明（自然照明）和空调。一般不会包含其他的电力消耗，尤其是其他家用电器和视听设备等。

### 新建筑

- 住宅的能量消耗必须低于50 kWh/ m²/yr乘以气候系数的最终值，一般是在40-70之间。
- 第三产业建筑的能量消耗必须比RT2005所规定的水平低50%。

### 现有建筑

- 住宅的能量消耗必须低于80 kWh/ m²/yr。
- 第三产业建筑的能量消耗必须比RT2005所规定的水平低40%。

## (3) Switzerland – MINERGIE 瑞士迷你能源标准

MINERGIE is a sustainability brand for new and refurbished low-energy buildings. There are four levels of certification – MINERGIE, MINERGIE-P, MINERGIE-ECO and MINERGIE-A.

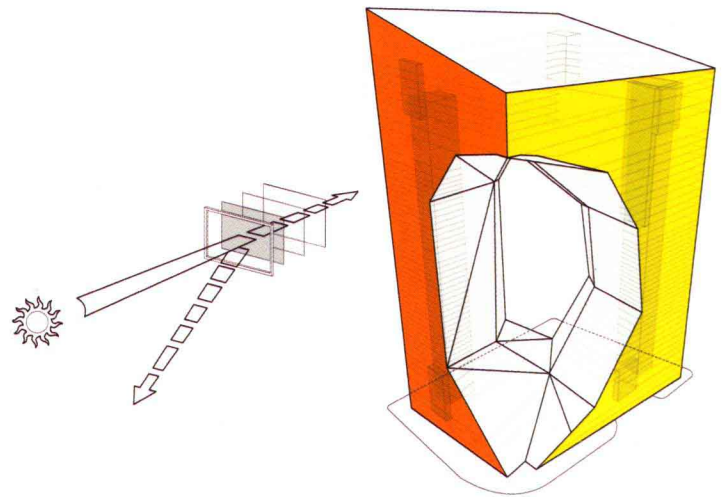
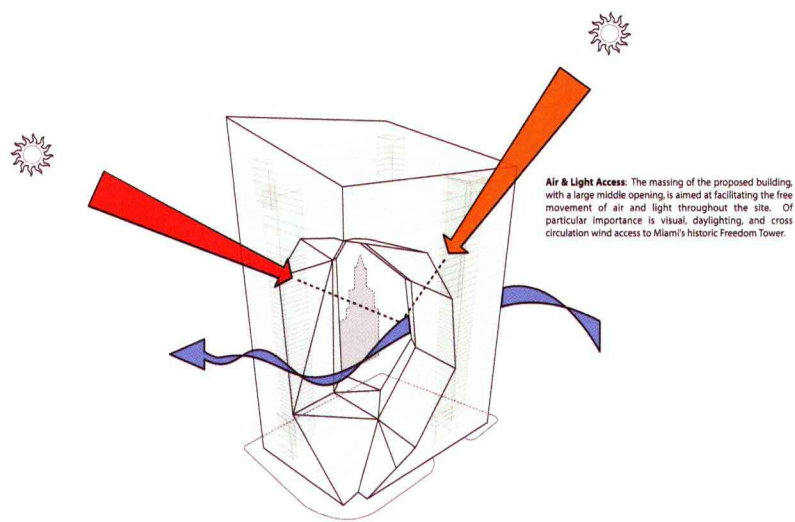
Comfort is at the heart of MINERGIE – the comfort of the users living or working in the building. A wholesome level of comfort is made possible by high-grade building envelopes and the continuous renewal of air.

Previously, for new single-family homes and apartment blocks 42 kWh/m²/yr must not be exceeded. For refurbishment projects the limiting value is 80 kWh/ m²/yr. Since 1 January 2008, the maximum energy consumption for new residential buildings is 38 kWh/ m²/yr and for renovated residential buildings 60 kWh/ m²/yr.

MINERGIE-P is a label for new and refurbished low-energy-consumption buildings that seeks an even lower energy consumption than the MINERGIE Standard.

MINERGIE-A is a label for new and refurbished low-energy-consumption buildings that seek "nearly zero-energy Buildings". It also takes into account the building gray energy, unlike MINERGIE and MINERGIE-P standards.

MINERGIE ECO is a label for new and refurbished low-energy-consumption



buildings that addresses ecological and social requirements. It can be combined with MINERGIE, MINERGIE-P, and MINERGIE-A, which are standards that focus more on energy consumption.

Eight Typical Characteristics of a MINERGIE House:

- ①. Compact shape
- ②. Airtight envelope
- ③. Uninterrupted thermal insulation
- ④. Controlled ventilation system with heat recovery
- ⑤. Adjustable external solar shading
- ⑥. Efficient equipment for heating, cooling and domestic hot water production
- ⑦. Water-based system for the distribution of heat for heating and cooling
- ⑧. Use of renewable energy sources

瑞士的迷你能源标准是适用于新建的和改造的低能耗建筑的可持续性标准。目前已形成迷你能源标准、迷你能源P级标准、迷你能源生态标准和迷你能源A级标准这4个等级。

迷你能源标准的核心是舒适度，旨在为用户打造舒适的居住与工作环境，这主要是通过高质量的建筑围护结构和空气的持续更新来实现的。

之前瑞士迷你能源标准规定新建住宅和公寓楼的最大能耗量是42 kWh/m<sup>2</sup>/yr，而改造项目的最大能耗量是80 kWh/m<sup>2</sup>/yr。从2008年1月1日起，新建住宅的最大能耗量被降至38 kWh/m<sup>2</sup>/yr，而改造项目的被降低到60 kWh/m<sup>2</sup>/yr。

迷你能源P级标准也同样适用于低能耗新建项目和改造项目，但相对于迷你能源标准，对建筑的能效性提出了更高标准。

迷你能源A级标准适用于新建项目和改造项目，但该标准所针对的项目基本上是接近于零能耗的建筑，与上述两项标准不同的是，A级标准将建筑的灰色能量也计入其中。

迷你能源生态标准主要强调的是生态与社会要求，而迷你能源标准、P级标准和A级标准更多的是注重能量消耗水平。生态标准可以和其他三项标准相结合。

符合迷你能源标准的住宅主要有以下8种典型特征：

- ①. 外形紧凑
- ②. 密封的围护结构
- ③. 不间断的隔热性
- ④. 受控通风及热回收系统
- ⑤. 可调式外部遮阳装置
- ⑥. 高效的供暖、制冷和热水供应设备
- ⑦. 用于分配供暖和制冷所需热量的水基系统
- ⑧. 可再生能源的使用

**(4) United States – ENERGY STAR, LEED & HERS**美国能源之星，绿色建筑评估体系和住宅能耗率标准

**ENERGY STAR**能源之星

ENERGY STAR is a joint program of the U.S. Environmental Protection

Agency and the U.S. Department of Energy helping to save money and protect the environment through energy efficient products and practices.

In 1992, ENERGY STAR as a voluntary labeling program was designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. The ENERGY STAR label is now on major appliances, office equipment, lighting, home electronics, and more. EPA has also extended the label to cover new homes and commercial and industrial buildings.

To earn the ENERGY STAR, a home must meet strict guidelines for energy efficiency set by the U.S. Environmental Protection Agency. These homes are at least 15% more energy efficient than homes built to the 2004 International Residential Code (IRC), and include additional energy-saving features that typically make them 20%–30% more efficient than standard homes.

ENERGY STAR qualified homes can include a variety of energy-efficient features that contribute to improved home quality and homeowner comfort, and to lower energy demand and reduced air pollution:

-Effective Insulation

Properly installed and inspected insulation in floors, walls, and attics ensures even temperatures throughout the house, reduced energy use, and increased comfort.

-High-Performance Windows

Energy-efficient windows employ advanced technologies, such as protective coatings and improved frames, to help keep heat in during winter and out during summer. These windows also block damaging ultraviolet sunlight that can discolor carpets and furnishings.

-Tight Construction and Ducts

Sealing holes and cracks in the home's "envelope" and in heating and cooling duct systems helps reduce drafts, moisture, dust, and noise. A tightly sealed home improves comfort and indoor air quality.

-Efficient Heating and Cooling Equipment

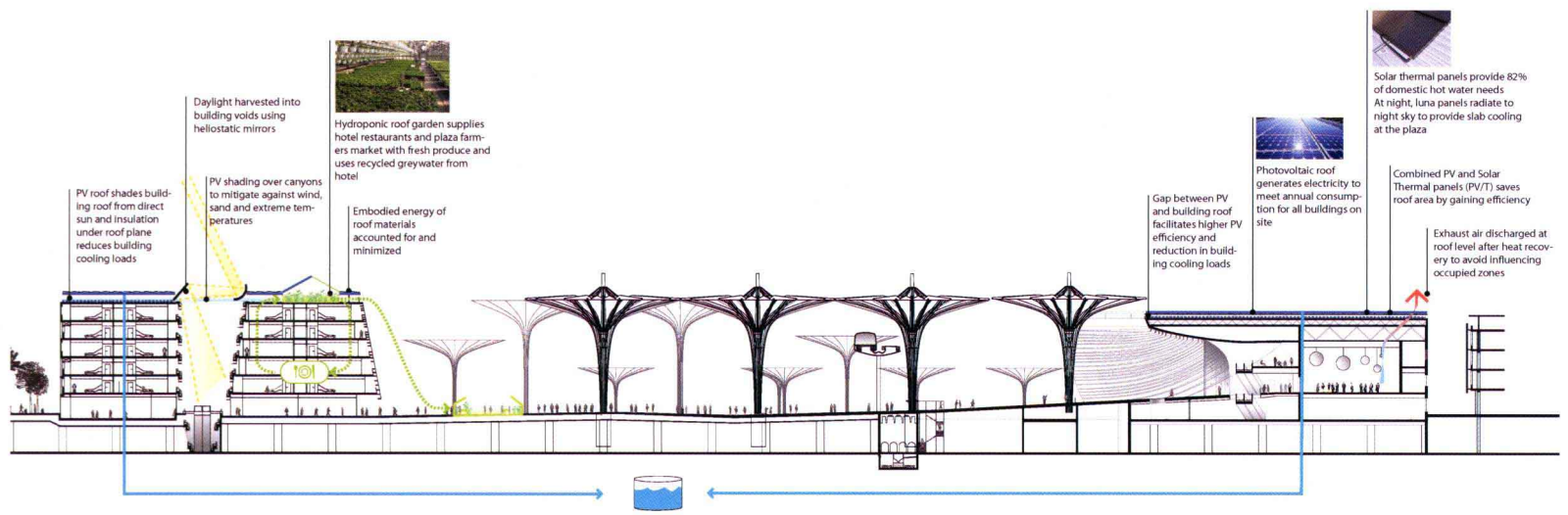
In addition to using less energy to operate, energy-efficient heating and cooling systems can be quieter, reduce indoor humidity. When properly installed into a tightly sealed home, this equipment won't have to work so hard to heat and cool the home.

-Efficient Products

ENERGY STAR qualified homes may also be equipped with ENERGY STAR qualified products — lighting fixtures, compact fluorescent bulbs, ventilation fans, and appliances, such as refrigerators, dishwashers, and washing machines.

-Third-Party Verification

With the help of independent Home Energy Raters, ENERGY STAR builder partners choose the most appropriate energy-saving features for their



homes. Additionally, raters conduct onsite testing and inspections to verify the energy efficiency measures, as well as insulation, air tightness, and duct sealing details.

能源之星是美国国家环保局和能源部联合推出的一项计划，主要目的是通过高效节能产品和实践来节约支出、保护环境。

1992年，能源之星作为一项自主性的标识系统被用来识别高效节能产品并促进其发展，旨在降低温室气体的排放。能源之星标识现已在主要的电力设备、办公设备、照明、家用电子产品以及其他产品上得到应用。美国国家环保局现已将这一标志的应用范围扩展到新建住宅、商业以及工业建筑上。

要获得能源之星标识，住宅必须符合美国国家环保局提出的严格的能效准则的要求。获得能源之星标识的住宅比按照2004国际住宅标准建造的住宅的能效性还要高15%。此外，再考虑到其他的一些节能特征，这类住宅的能效性比标准住宅要高20%~30%。

获得能源之星标识的住宅包含各种节能特征，有助于提升住宅的质量和舒适性，降低能源需求和空气污染。

#### -高效保温

在住宅的地板、墙体和阁楼等结构中添加合适的保温材料和产品可以使室内的温度维持在一个特定的水平，减少了能量的使用，同时也使环境更为舒适。

#### -高性能窗户

高性能的窗户通常会采用保护性覆盖层和改良框架等先进技术，在冬天的时候，可以防止室内暖空气的扩散，而在夏天，可以阻挡室外的热空气。这些窗户还能阻挡紫外线的射入，防止地毯和室内陈设褪色。

#### -紧密的结构与管道系统

将建筑的围护结构以及管道系统中的孔眼和裂缝密封起来可以减少涌入室内的气流、水气、灰尘和噪音。高度密封的住宅改善了室内的空气质量，提升了舒适性。

#### -高效供暖与制冷设备

高效的供暖与制冷设备不仅可以降低能量需求，也可以减少室内的湿气，并且，高效的设备运转起来产生的噪音也少一些。若能够合理地安装在一个气密性良好的住宅内，设备的运转也会变得更为容易。

#### -节能产品

获得能源之星标识的住宅内还可以配备能源之星认证的产品，如照明装置、紧凑型节能灯、通风风扇以及电冰箱、洗碗机、洗衣机等设备。

#### -第三方验证

住宅能效评估者可以帮助建筑商选择最合适的节能措施，同时，他们还可以实行现场测试以及检查以验证这些节能措施的效果和住宅的保温、气密性和管道密封等细节。

#### LEED绿色建筑评估体系

LEED (Leadership in Energy & Environmental Design) is an internationally recognized green building certification system developed by the U.S. Green Building Council (USGBC) in March 2000.

LEED promotes sustainable building and development practices through a suite of rating systems that recognize projects implementing strategies for better environmental and health performance. The LEED rating systems

are developed through an open, consensus-based process led by LEED committees, diverse groups of volunteers representing a cross-section of the building and construction industry.

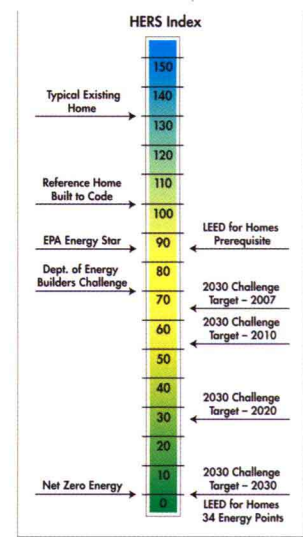
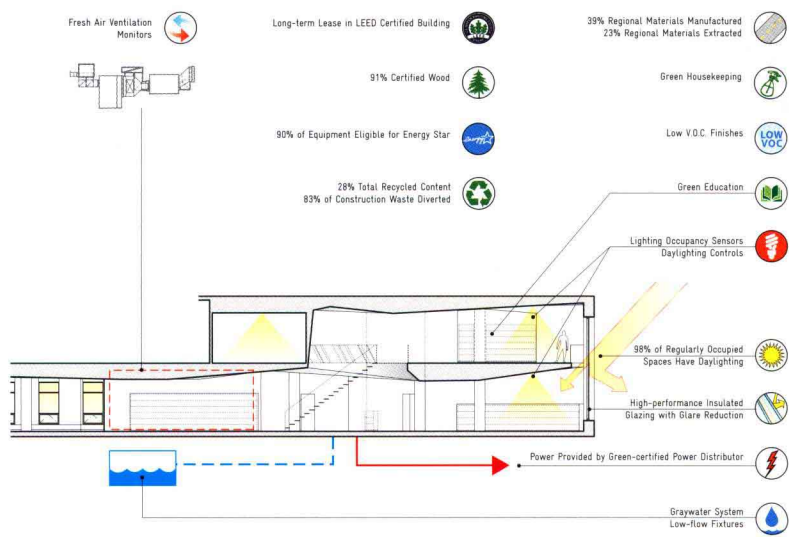
LEED is flexible enough to apply to all building types – new construction and existing buildings ranging from commercial, residential, schools to healthcare, etc. It works throughout the building lifecycle – design and construction, operations and maintenance, tenant fitout, and significant retrofit.

LEED consists of a suite of rating systems for the design, construction and operation of public buildings, homes and neighborhoods:

- ① LEED for New Construction Rating System – for commercial and institutional projects
- ② LEED for Core & Shell Rating System – for base building elements such as structure, envelope and the HVAC system
- ③ LEED for Schools Rating System – addressing issues such as classroom acoustics, master planning, mold prevention and environmental site assessment
- ④ LEED for Retail Rating System – LEED 2009 for Retail: New Construction & Major Renovations and the LEED 2009 for Retail: Commercial Interiors Rating Systems
- ⑤ LEED for Healthcare Rating System – inpatient, outpatient and licensed long-term care facilities, medical offices, assisted living facilities and medical education and research centers
- ⑥ LEED for Commercial Interiors Rating System – certifying high-performance green interiors that are healthy, productive places to work, are less costly to operate and maintain; and have a reduced environmental footprint
- ⑦ LEED for Existing Buildings Rating System – addressing whole-building cleaning and maintenance issues (including chemical use), recycling programs, exterior maintenance programs, and systems upgrades
- ⑧ LEED for Neighborhood Development Rating System – verifying that a development's location and design meet accepted high levels of environmentally responsible, sustainable development
- ⑨ LEED for Homes Rating System – promoting the design and construction of high-performance green homes

LEED evaluates building performance in a series of key areas: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, Indoor Environmental Quality, Locations & Linkages, Awareness & Education, Innovation in Design, Regional Priority.

LEED points are awarded on a 100-point scale, and credits are weighted to reflect their potential environmental impacts. Additionally, 10 bonus credits are available, four of which address regionally specific environmental



issues and six for innovation aspect. A project must satisfy all prerequisites and earn a minimum number of points to be certified.

Buildings can qualify for four levels of certification:

Certified: 40 - 49 points

Silver: 50 - 59 points

Gold: 60 - 79 points

Platinum: 80 points and above

LEED是一个国际公认的绿色建筑评估认证系统，由美国绿色建筑协会于2000年3月建立并推行，目前在世界各国的各类环保建筑评估、绿色建筑评估以及建筑可持续性评估标准中被认为是最完善、最有影响力的评估标准。

LEED通过一套评估系统评价建筑的环保及健康指标，倡导可持续的建筑设计与开发理念。LEED评分系统是通过公开、协商的方式，在LEED委员会的领导下制定的，参与者包括各类自愿者团体，代表了建筑与建造行业的不同领域。

LEED的灵活性使其适用于所有的建筑类型，包括新建建筑及现有建筑，范围涵盖商业、住宅、学校、医疗等。这一评估体系可以应用在建筑的整个生命周期中，从设计、施工、运营到维护、装修以及重大改造。

LEED包含一系列评估体系用来评价公共建筑、住宅以及社区的设计、施工以及运营：绿色建筑设计及施工：

- ① LEED新建项目评估体系——针对商业与公共机构
- ② LEED核心与外壳评估体系——针对基本的建筑元素，如结构、围护以及加热、通风和空调系统
- ③ LEED学校评估体系——强调教室的传音性、总体规划、防霉效果以及环境评估
- ④ LEED零售建筑评估体系——包含2009LEED零售：新建项目及重大改造项目评估体系，2009LEED零售：商业建筑室内评估体系
- ⑤ LEED医疗建筑评估体系——适用于住院护理设施、门诊设施、获得许可的长期护理设施、医疗办公室、辅助生活设施以及医学教育和研究中心
- ⑥ LEED商业建筑室内评估体系——验证室内环境的健康与有益性，运营与维护的低成本以及环境足迹的减少
- ⑦ LEED现有建筑评估体系——强调整个建筑的清洁与维护（包括化学物质的应用）、资源循环再利用、外部维护以及系统升级
- ⑧ LEED社区发展评估体系——从选址及设计验证社区项目的环境友好性及可持续发展
- ⑨ LEED住宅评估体系——促进高效绿色住宅的设计与建造

LEED从一些关键方面来评估建筑的性能，主要包括可持续性选址、水利用率、能源与空气、材料与资源、室内环境质量、位置与关联性、意识与教育、创新设计和地域优越性。

LEED适用的是百分制的评分策略，反映出建筑潜在的环境影响力。除100分的基本分外还有10个附加分值项目，包括4分的地域优先分和6分的设计创新分。项目在满足所有先决条件的基础上，还需要达到某个特定认证级别的最低分数要求。

LEED分四个认证等级：

认证级：40-49分

银级：50-59分

金级：60-79分

铂金级：80分以上

### HERS (Home Energy Rating System)住宅节能等级评定制度

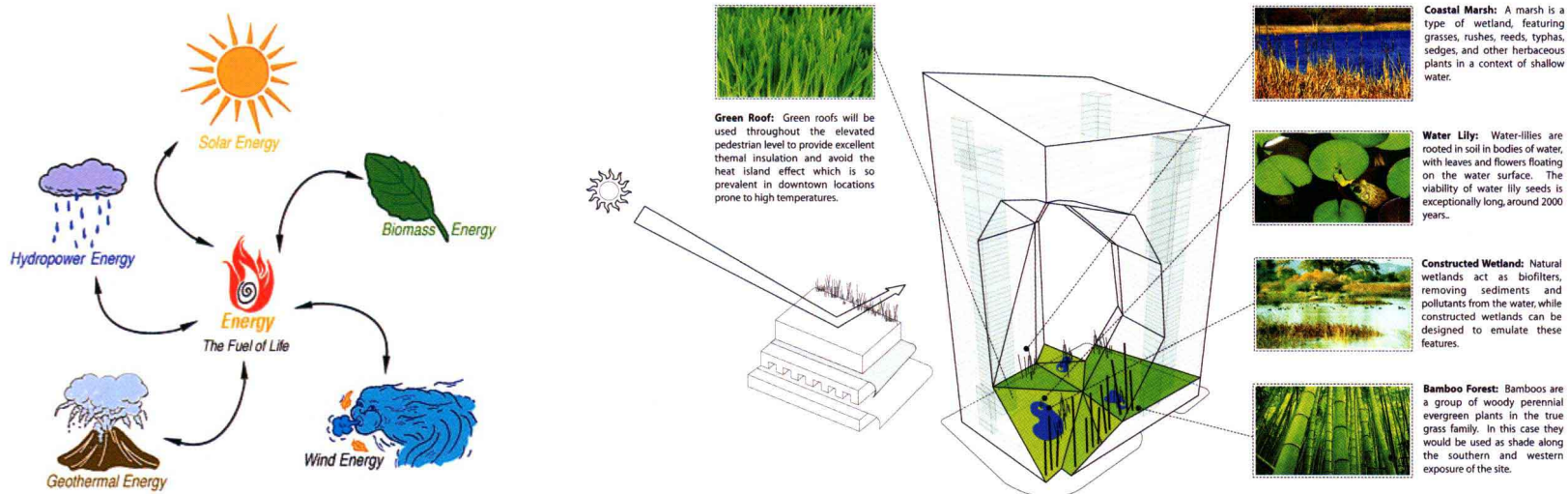
A Home Energy Rating is a measurement of a home's energy efficiency, used primarily in the United States. It can be used for either existing homes or new homes. A home energy rating of an existing home allows a homeowner to receive a report listing options for upgrading a home's energy efficiency. The homeowners may then use the report to determine the most effective ways in which to upgrade the home's energy efficiency. A home energy rating of a new home allows buyers to compare the energy efficiency of homes they are considering buying.

The Rating provides a relative energy use index – HERS Index. The scoring system compares the home being tested to a HERS Reference Home, which has a HERS Index of 100 (based on the 2006 International Energy Conservation Code). A "Net Zero" energy home will have a HERS Index of 0. The lower a home's HERS Index, the more energy efficient it is. Each 1-point decrease in the HERS Index is equal to a 1% reduction in energy consumption. For example, a home with a HERS Index of 85 is 15% more energy efficient than the Reference Home. A home with a HERS Index of 85 will also qualify for the Energy Star Label.

HERS主要是在美国使用的住宅节能等级评定制度，适用于现有住宅以及新建住宅。对现有住宅的节能等级评定可以为业主提供一个有关住宅能效提升的报告，业主可以根据报告找出最有效的方式来优化住宅的能源利用效率。对新建住宅的节能等级评定便于住宅购买者对各个住宅进行能效对比，从而做出更明智的购买选择。住宅节能等级评定制度提出了一个相对的能量利用指标——HERS指标。评分系统设置了一个HERS参考住宅，该住宅的HERS指标为100（基于2006年的国际节能规范），评分系统会将待评定的住宅与参考住宅进行对比，从而确定待评定住宅的HERS指标。零能耗住宅的HERS指标为0。HERS指标越低，表示该住宅的能效越高。HERS指标每降一分，就代表能量消耗降低1%。例如，HERS指标为85的住宅比参考住宅的能效要高15%。并且，HERS指标为85的住宅也足以获得能源之星标签。

### (5) UK – National Home Energy Rating (NHER) and Standard Assessment Procedure (SAP)英国国家房屋能源等级制和标准评估程序

The National Home Energy Rating Scheme (NHER), owned and operated by National Energy Services (NES), is launched in 1991 as both a UK accreditation scheme for energy assessors and a rating scale for the energy efficiency of housing. It is a method of assessing the energy performance and fuel cost of a dwelling. The NHER scale for newly built dwellings is from 0 to 20, with 20 the best. A dwelling with a NHER rating of 20 achieves zero CO2 emissions along with zero net running costs. The NHER rating is not a statutory requirement. It is often used by affordable housing providers to give a good indication of potential running costs of



new properties.

The Standard Assessment Procedure (SAP) was developed by the Building Research Establishment in 1992. It is the UK Government's recommended method system for measuring the energy rating of residential dwellings. It assists in delivering many of the Governments energy and environmental policy objectives. SAP typically qualifies a dwelling's performance in terms of energy use per unit floor area, a fuel cost based energy efficiency rating and emissions of CO<sub>2</sub>. These indicators are based on estimation of space heating, domestic hot water, lighting and ventilation. According to SAP, dwellings are rated from 0 - 100, the higher the rating figure the more energy efficient.

SAP and the NHER scales measure slightly different things. The SAP takes no account of the geographical location or local positioning of the house. The NHER, on the other hand, takes account of factors such as occupancy, orientation and appliance use to give a more accurate calculation of CO<sub>2</sub> emissions and running costs for a specific dwelling, and so is a better indicator of running costs.

国家房屋能源等级制NHER是受英国国家能源服务公司支配及管理的制度，于1991年推出。该制度是英国能量评估者的认证体制，也被用来评定房屋的能效等级。它是一种评定住宅能源绩效以及燃料消耗量的方法。根据NHER，新建住宅的能效等级范围为0-20，20表示能效最高。能效等级为20的住宅的碳排放以及净运营成本基本上为0。NHER并不是一项法定要求，对经济适用房供应者来说，它能很好地体现新房产的潜在运营成本。

标准评估程序SAP是英国建筑研究院于1992开发的一套程序，是英国政府推荐的用于计量住宅能效等级的体系，有助于宣传政府的能源与环境政策目标。SAP通常是通过住宅每单位体积的能耗量，燃料成本以及二氧化碳排放量来考量住宅的能效性。这些计量指标是基于对空间供暖、热水、照明以及通风所产生的能耗量及排放量的估算。SAP将住宅等级划为0-100，数据越大，能效性越高。

SAP和NHER的计量内容稍微有些不同。SAP并没有计算住宅的地理位置，相反，NHER不仅涵盖住宅的地理位置，还包括其朝向以及电器产品的使用等，因此，它能够更为准确地提供住宅的二氧化碳排放量以及运营成本。

#### (6) Canada – EnerGuide加拿大能源指南

EnerGuide is an energy rating program of Canada for labeling and rating of the energy consumption or energy efficiency of specific products. EnerGuide labeling exists for appliances, heating and cooling equipment, houses and vehicles.

EnerGuide for Houses (EGH) is developed by the Office of Energy Efficiency of Natural Resources Canada (NRCAN). EnerGuide includes a house energy evaluation, including tests to find air leakage and the energy efficiency of its heating. It was designed to help Canadians reduce their greenhouse gas emissions and to save energy. The EnerGuide for New

Houses (EGNH) program, a sister program of EnerGuide for Houses, helps Canadians plan and build new homes that are cost-effective and energy efficient, that lower greenhouse gas emissions and save energy.

In addition to evaluating the design trade-offs that affect the annual energy usage of the home it is also a ranking system. The EnerGuide for Houses scale goes from 0-100 with 0 being the least efficient and 100 being the most energy efficient.

**EnerGuide Rating System for New Homes**

Type of House	Rating
New house built to building code standards	65 ~ 72
Energy-efficient new house	73 ~ 79
Highly energy-efficient new house	80 ~ 90
House requiring little or no purchased energy	91 ~ 100

**EnerGuide Rating System for Existing Homes**

Type of House	Rating
Older house not upgraded	0 ~ 50
Upgraded older house	51 ~ 65
Energy-efficient upgraded older house	66 ~ 74

能源指南在加拿大主要用来标示特定产品的能量消耗以及能量使用效率，涵盖电器产品、供暖与制冷产品、住宅以及交通工具。

EnerGuide的管理部门——加拿大自然资源部下属的能效办公室推出了两个标识体系EGH和EGNH，分别针对现有建筑和新建建筑。这两项标识体系不仅仅关注建筑的能耗，还考虑了气密性、空气质量等。一方面，按照EGH的标准，对现有建筑进行一定的改造或提出一些措施可以降低温室气体排放，节约能源；另一方面，EGNH可以协助业主建造能效等级更高、温室气体排放更少的建筑。

除了用来比较与评定住宅的年能量消耗以外，能源指南也可以作为评级系统对住宅的能效性进行评分，分值在0~100之间波动，0代表最低的能效性，而100代表最高的能效性。

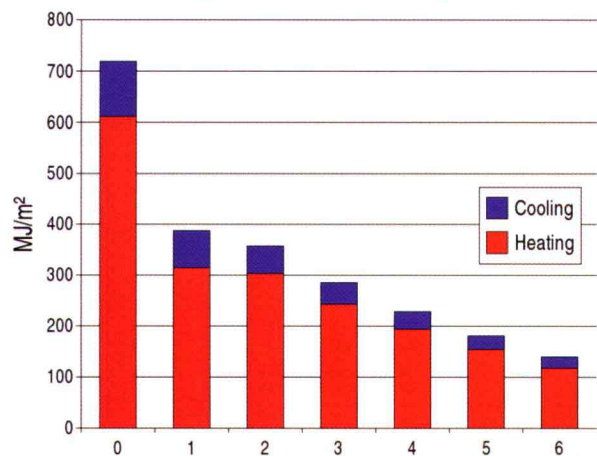
**新建住宅的能效评分**

住宅种类	分值
按建筑规范建造的新住宅	65 ~ 72
具有一定能效性的新住宅	73 ~ 79
具有高能性的新住宅	80 ~ 90
不需要或只需要很少的外界能量供应的新住宅	91 ~ 100

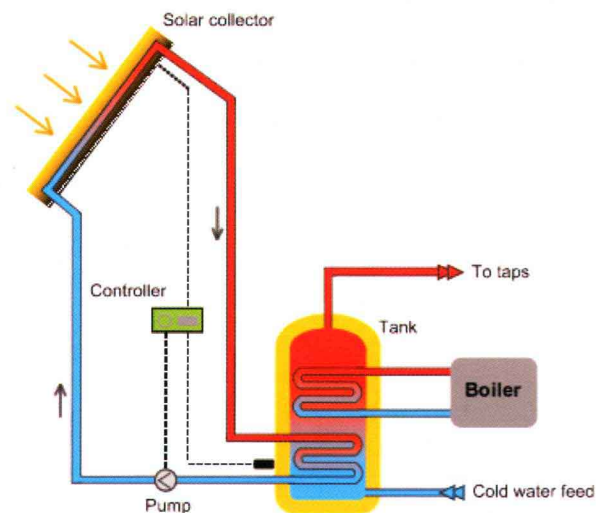
**现有住宅的能效评分**

住宅种类	分值
未改善的现有住宅	0 ~ 50
已改善的现有住宅	51 ~ 65
已改善的具有高能性的住宅	66 ~ 74

## Annual energy usage for heating and cooling



Australian House Energy Rating



### (7) Australia – House Energy Rating 澳大利亚住宅能效评级制度

A House Energy Rating is an index of a building's thermal performance (i.e. heating and cooling requirements) for residential homes in Australia.

#### 6-Star Rating

A 6-Star rating indicates that a building achieves a very high level of thermal energy performance. Houses in the suburb of Aurora, Victoria will have an energy efficiency rating of at least 6 stars.

#### 5-Star Rating

A 5-Star rating indicates that a building achieves a high level of thermal energy performance, and will require minimum levels of heating and cooling to be comfortable in winter and summer. Houses which achieve a 5 star rating, compared to the average 2 star home, should be more comfortable to live in, have lower energy bills, and costs to install heating and cooling equipment should also be lower.

Energy assessments take into account different climatic conditions in different parts of the country and are benchmarked according to average household energy consumption particular to a given climatic region. The house energy rating does not currently include the efficiency of any appliances fitted or used within the house. There are also no physical testing requirements, so air tightness testing is not required.

住宅能效评级制度主要是评定澳大利亚住宅的热性能（供热和制冷要求）的一项指标。

#### 六星级

六星级意味着该建筑具有最高水平的热性能。在澳大利亚维多利亚州的欧罗拉郊区，住宅的能效至少是六星级。

#### 五星级

五星级的住宅具有较高水平的热性能，在夏日的时候，只需要最低水平的能量用于制冷，同样的，在冬天，也只需要最低水平的能量用来供热。比起一般的二星级的住宅，五星级的更为舒适，且能量成本较低，用来安装制冷与供热系统的成本也更低。这一能效评级制度也考虑到了澳大利亚各个地区的不同气候条件，以某个特定气候区的平均能耗量作为基准。但是该制度并未计算住宅内的任何设备的能效性，对气密性测试也没有提出任何要求。

### (8) China – Evaluation Standard of Green Building 中国绿色建筑评价标准

Green building (also known as green construction or sustainable building) refers to a structure and using process that is environmentally responsible and resource-efficient throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort.

"Evaluation Standard of Green Building", coming into effect on June 1st 2006, is a national standard instituted by the Ministry of Housing and Urban-

Rural Development of the People's Republic of China. It evaluates residential buildings as well as public ones like office building, shopping malls and hotels, etc. The standard contains six evaluation indexes: site conservation & exterior environment, energy saving & utilization, water saving and utilization, building material saving and utilization, interior environmental quality and operation management. There are control items, general items and optional items for every index. Control items are essential to green buildings, while optional items are usually high requirements that are difficult to meet. Green buildings will be classified into three levels – Grade A, Grade B and Grade C from low to high – according to their degree of conformity to the general items and optional items.

绿色建筑是指在建筑的全寿命周期内（选址、施工、运营、维护、修缮、拆迁），最大限度地节约资源（节能、节地、节水、节材）、保护环境和减少污染，为人们提供健康、适用和高效的使用空间，与自然和谐共生的建筑。

《绿色建筑评价标准》是2006年由中华人民共和国建设部组织编制的适用于绿色建筑的国家标准，自2006年6月1日起实施。本标准用于评价住宅建筑和办公、商场和宾馆等公共建筑。形成了六大技术体系评价指标：节地与室外环境、节能与能源利用、节水与水资源利用、节材与材料资源利用、室内环境质量及运营管理。每类指标包括控制项、一般项与优选项。其中，控制项为评为绿色建筑的必备条款；优选项主要指实现难度较大、指标要求较高的项目。按满足一般项和优选项的程度，绿色建筑划分为由低到高一星级、二星级、三星级三个等级。

## 3 Low-energy Technologies 低能耗技术

### (1) Active Solar Technologies 主动式太阳能技术

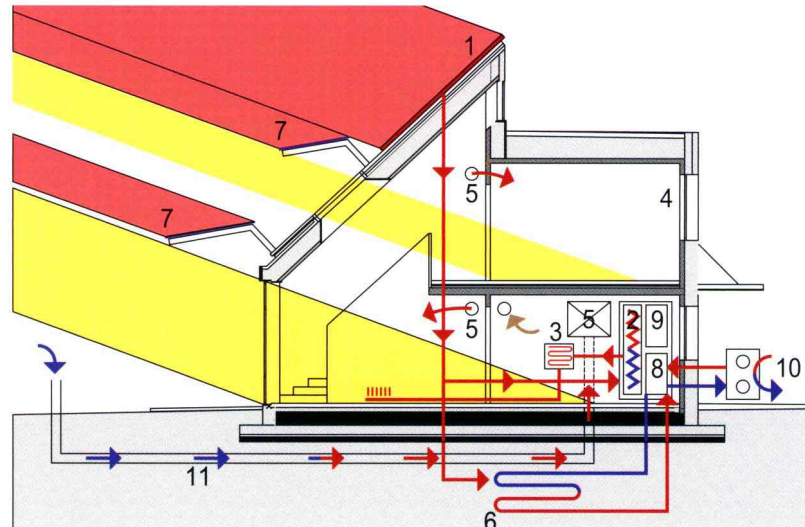
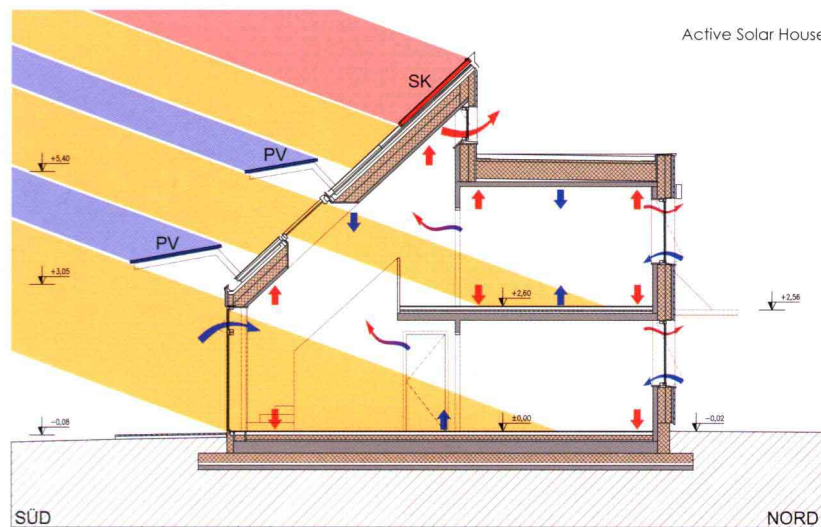
Active solar technologies usually consist of a solar collecting device that is designed to capture the sun's energy; it can be used to store or transfer heat energy in water or air. Unlike passive solar technologies there is usually a moving part involved, usually electrical or mechanical equipment, such as pumps and fans.

#### Solar Collectors

Solar collectors are at the heart of most active solar energy systems. They are the key component of active solar systems, and are designed to meet the specific temperature requirements and climate conditions for the different end-uses. The collector absorbs the solar energy and changes it into heat energy. The heat can then be used to provide heated water for use, to provide space heating or cooling, or for many other applications where fossil fuels might otherwise be used.

#### Photovoltaics

Photovoltaics (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using



semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Photovoltaic arrays are often associated with buildings: either integrated into them, mounted on them or mounted nearby on the ground.

### Solar Water Heaters

Solar water heaters use the sun to heat either water or a heat-transfer fluid in collectors. That water is then stored for use as needed. A typical system will reduce the need for conventional water heating by about two-thirds, minimizing the cost of electricity or fossil fuel and the environmental impacts associated with their use.

主动式太阳能技术通常是运用一种特殊的装置来采集太阳能，然后将其储存起来或者转化为水和空气中的热量。与被动式太阳能技术不同的是，主动式太阳能技术通常都会有可动元件的参与，通常是电力或者机械设备，如水泵、风扇等。

### 太阳能集热器

太阳能集热器在大部分的主动式太阳能系统中属于核心部分，作为系统的关键组成部分，太阳能集热器的设计通常需要根据其最终用途满足特定的温度要求和气候条件。集热器吸收太阳能后将之转化为热量，用来热水、为室内供热或制冷提供能量，或者代替化石燃料为其他各种设备提供能量。

### 光伏系统

光伏发电系统是一种利用太阳能电池半导体材料的光伏效应，将太阳光辐射能直接转换为电能的一种新型发电系统。该系统利用太阳能光伏板进行发电，光伏板是由一系列包含光伏材料的太阳能电池组成。光伏阵列通常被嵌入建筑中、安装在建筑顶部或者安装在建筑附近的地面上。

### 太阳能热水器

太阳能热水器利用太阳能来加热集热器中的水或者其他传热流体，经过加热的水会被储存起来在需要的时候加以利用。典型的太阳能热水器能够将传统热水的需求降低约三分之二，大大地减少用电与化石燃料的成本，同时降低了对环境的负面影响。

## (2) Passive Solar Building Design 被动式太阳能建筑设计

The key elements of passive design are: building location and orientation on the site; building layout; window design; insulation (including window insulation); thermal mass; shading; and ventilation. Each of these elements works with others to achieve comfortable temperatures and good indoor air quality.

In passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. This is called passive solar design or climatic design because, unlike active solar heating systems, it doesn't involve the use of mechanical and electrical devices. Close attention will be paid to the site and location of the building, the prevailing climate, the design and construction, the solar orientation, the positioning of glazing

and shading elements, etc.

Following passive solar building techniques, where possible buildings are compact in shape to reduce their surface area, with principle windows oriented towards the equator - south in the northern hemisphere and north in the southern hemisphere - to maximize passive solar gain. However, the use of solar gain, especially in temperate climate regions, is secondary to minimizing the overall house energy requirements. In climates and regions needing to reduce excessive summer passive solar heat gain, whether from the direct or reflected sources, can be done with a Brise soleil, trees, attached pergolas with vines, vertical gardens, green roofs, and other techniques.

All of these elements work alongside each other and therefore should be considered holistically. For example, large windows that admit high levels of natural light might also result in excessive heat gain. Similarly, opening windows that provide ventilation will also let in noise.

被动式设计的关键在于建筑的选址与朝向、建筑的布局、窗户的设计、隔热（包括窗户的隔热）、热质、遮阳和通风。各个要素之间相互配合以获得舒适的温度和较高的室内空气质量。

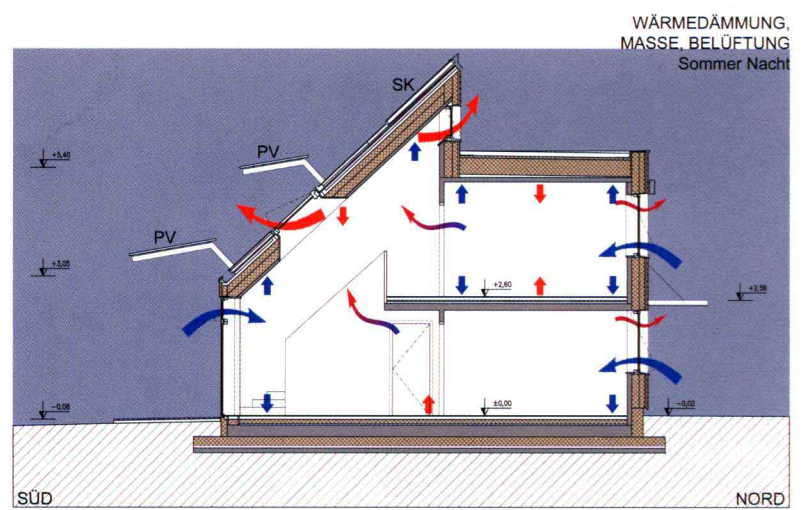
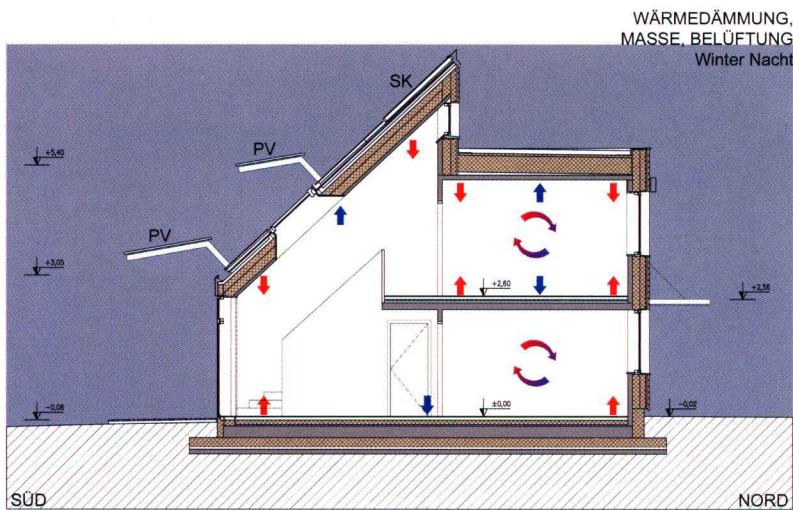
被动式太阳能建筑利用窗户、墙壁、地板的设计，在冬天的时候收集、储存和散布以热量形式存在的太阳能，而在夏天的时候阻隔太阳热量的吸收。之所以称为被动式太阳能设计，是因为它不需要借助电力和机械设备来实现能量的有效利用。被动式太阳能建筑设计更多关注的是建筑的选址、气候、设计与施工、阳光朝向、窗子的朝向以及遮阳装置等。

运用被动式太阳能技术的建筑形式上都比较紧凑，这样可以减少表面积，建筑的窗户都朝向赤道，也就是说，北半球的建筑窗户都朝南，而南半球则相反，这样可以最大化被动式太阳能的吸收。但是，在温带区域，对所获取的太阳能的利用往往是次要的，最主要的还是减少建筑的整体能量需求。在其他某些区域，夏天的时候往往需要减少直接或者间接获取的太阳能，这可以通过遮阳屏板、绿树、凉棚、垂直花园、绿色屋顶等技术来实现。

所有这些要素都是一起运作，所以设计时需要进行综合考虑，例如，大的窗口可以实现更多的自然光的摄入，但同时可能会导致过多的热量进入室内；同样的，窗口在帮助建筑实现自然通风的同时，也有可能导致过多噪音干扰室内环境。

## (3) Renewable Energy 可再生能源

Renewable energy, occurring naturally and repeatedly, can be provided by water, wind, sun or geothermal heat, from the ground. Renewable energy can also be produced from biomass and plant sources such as wood or crops, grown specifically as a fuel. Most renewable energy production is large scale but some renewable technologies are suited to small off-grid applications. The Renewable Energy measures featured include: Solar PV, Solar Tiles, Small Wind Turbines, Small Scale Hydro and more.



### Solar PV Panels

Solar photovoltaics or solar PV for short is a technology with which daylight is converted into electrical power. It uses energy from the sun to create electricity that will operate electrical appliances and lighting. Solar power requires only daylight, not necessarily sunlight, and is therefore capable of generating electricity on a cloudy day. Solar panels work equally well in urban or rural locations. They can be installed on the roofs of most homes and can easily be connected to a building's electricity supply.

### Solar Roof Tiles

Solar tiles operate on the same principle as solar PV panels. The advantage of solar tiles is that they are manufactured to the same modular size as large format roof tiles. They can be integrated into a new roof at the time of construction or into an existing roof when the roof covering is replaced.

### Small Wind Turbines

Small wind turbines harness the power of the wind and use it to generate electricity. Small wind turbines can produce electricity to power lighting and domestic appliances in a typical home. When considering whether to invest in a wind turbine system to provide electricity for a home, it is important to know if there are any significant nearby obstacles such as buildings or trees that are likely to reduce the wind speed or increase wind turbulence.

可再生能源是自然界中可以不断再生并有规律地得到补充或重复利用的能源，可以通过水、风、太阳、地热、生物质能、生物和植物等资源获取。大多数可再生能源的生产规模很大，但一些可再生能源技术适用于小型离网系统。可再生能源措施包括：太阳能光伏、太阳能瓦片、小型风力发电机、小型水力发电等。

#### 太阳能光伏电板

太阳能光伏发电是将日光转换成电能的技术。它使用来自太阳的能量来发电，供电器和照明设备使用。太阳能发电需要白天的光亮，但不一定需要有阳光，因此在阴天也能够产生电力。太阳能电池板在城市及农村地区都可以使用。它们可以安装在大多数家庭的屋顶，并且可以很容易地连接到建筑物的电力供应系统中。

#### 太阳能瓦片

太阳能瓦片与太阳能光伏电池板的原理相同。太阳能瓦片的优势是，它们的标准化尺寸与大型屋顶瓦片一样。在施工时间，可以将它们集成到新的屋顶中，旧屋顶进行更换时，也可以安上太阳能瓦片。

#### 小型风力发电机

小型风力发电机利用风力来发电，为照明系统和家用电器提供电力。在考虑是否进行风力发电系统投资时，必须要注意观察建筑附近是否有其他建筑物或树木等有可能减少风速或增加风湍流的障碍物。

### (4) Techniques and Materials of Thermal Insulation 保温技术及保温材料

Building insulation materials are used in the construction or renovation of buildings. The materials are used to reduce heat transfer and are

employed in varying combinations to achieve the desired outcome, usually thermal comfort with reduced energy consumption. In the average house, well designed and installed insulation can reduce the amount of heat lost through the building envelope by at least half.

Insulation can be categorized by its form into structural or non-structural insulation. Non-structural forms include fiberglass batts and blankets (glass wool), loose-fill (including cellulose), spray foam, and panels. Structural forms include insulating concrete forms, structured panels, and straw bales. Glass wool is an insulating material made from fiberglass, arranged into a texture similar to wool. It consists of intertwined and flexible glass fibers, which causes it to "package" air, resulting in a low density that can be varied through compression and binder content. It can be a loose fill material, blown into attics, or, together with an active binder sprayed on the underside of structures and panels that can be used to insulate flat surfaces.

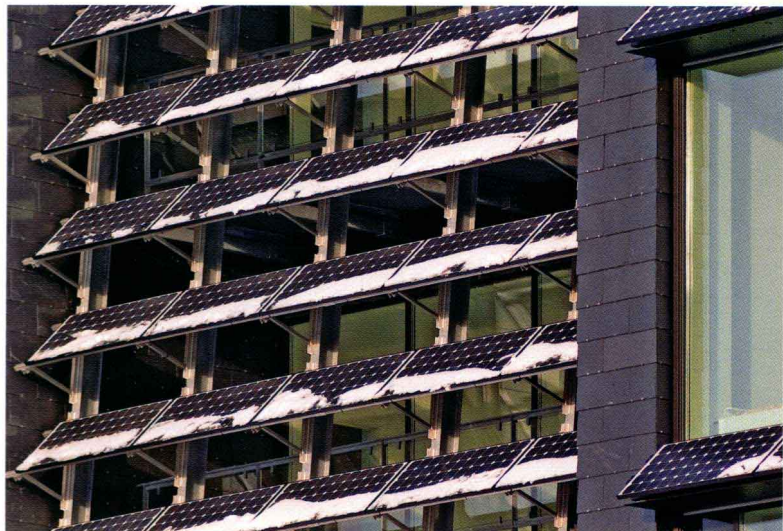
Cellulose insulation is a kind of plant fiber used in wall and roof cavities to separate the inside and outside of the building thermally and acoustically. The thermal conductivity of loose-fill cellulose is approximately  $40 \text{ mW/m}\cdot\text{K}$  – an R-value of which is about the same as or slightly better than glass wool or rock wool. Cellulose is very good at fitting around items in walls like pipes and wiring, leaving few air pockets that can reduce the overall efficiency of the wall.

Insulating Concrete Form (ICF) is a system of formwork for concrete that stays in place as permanent building insulation for energy-efficient, cast-in-place, reinforced concrete walls, floors, and roofs. The forms are interlocking modular units that are dry-stacked (without mortar) and filled with concrete. ICF structures are much more comfortable, quiet, and energy-efficient than those built with traditional construction methods. Its thermal resistance is typically above  $3 \text{ K}\cdot\text{m}^2/\text{W}$ ; this results in saving energy compared with uninsulated masonry.

Structural insulated panels (SIPs), are a composite building material. They consist of an insulating layer of rigid polymer foam sandwiched between two layers of structural board. The board can be sheet metal, plywood, cement or oriented strand board (OSB) and the foam either expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane foam. A well-built home using SIPs will have a tighter building envelope and the walls will have higher insulating properties, which leads to fewer drafts and a decrease in operating costs.

在建筑的建造与改造中，通常会应用建筑保温材料来减少热量的传递，通过保温材料的各种组合来取得预期效果，如减少能量消耗和提升热舒适度。在一般的住宅中，良好的保温设计与保温结构的安装能够将通过建筑围护结构散失的热量降低百分之五十。





从形态上划分，保温材料可以分为结构性保温材料和非结构性保温材料。非结构性保温材料包括玻璃纤维棉和玻璃纤维毡（玻璃棉）、松散充填料（含纤维素）、喷雾泡沫和保温板。结构性保温材料包括绝热混凝土模板、结构性保温板和稻草砌块。

玻璃棉是由玻璃纤维制成的保温材料，其结构类似于羊毛，通过柔软的玻璃纤维相互交织而成，因此内部有空隙，密度很低，可以通过挤压和粘合剂改变其形状。玻璃棉可以作为松散充填料填充到阁楼层中，或者与活性粘合剂一起喷在各种结构和板材的内层，使得各种平面表层具有保温隔热性。

纤维素保温材料是一种植物纤维，主要用在墙体和屋顶的中空部分里，取得隔热和隔音的效果。松散填充纤维素制品的热导率大约是 $40 \text{ mW/m}\cdot\text{K}$ ，R值比玻璃棉的稍微高一点。纤维素可以很好地填充在墙体中的管道和电线周围，留下很少的气穴，从而不会减少整个墙体的能效性。

绝热混凝土模板是一种永久性的建筑隔热模架，可以进行现场混凝土浇筑，打造高能效的钢筋混凝土墙体、地板和屋顶。这种模板是由一系列的模块组成，模块之间通过干式堆积（不用砂浆）相互连接，内浇筑钢筋混凝土。与传统的施工方法相比，绝热混凝土模板结构能效性更高，能够提供更为舒适和安静的空间。该结构的隔热性通常高于 $3 \text{ K}\cdot\text{m}^2/\text{W}$ ，这也使得建筑的能耗量比利用一般的石工技术建成的房屋要低。

结构性保温板是一种复合建筑材料，通过将一层硬质聚合泡沫置于两层结构板中间而形成。结构板可以采用金属片、胶合板、水泥或定向结构板，而泡沫可以采用膨胀式聚苯乙烯泡沫、挤塑式聚苯乙烯泡沫和聚氨酯泡沫。采用结构性保温板的住宅其围护结构和墙体具有较高的保温性能，所以可以减少冷空气的进入，降低供热系统运行成本。

### (5) Airtightness 气密性

In cold weather, warm air from inside the home passes naturally through the building envelope into the cold air outside. This warm air draws in cold air from the outside which enters the home as draughts. This is uncomfortable for occupants and an expensive waste of energy.

The designers of low-energy houses will employ airtightness measures to reduce costly heat losses through the building envelope. The features of an airtight house include: breather membranes, multi foil insulation, door draught excluders, triple glazing and more.

Warm air leaking out through gaps in a house's external envelope is a major cause of heat loss and, consequently, wasted energy. Improving airtightness in houses reduces the uncontrolled flow of air through gaps and cracks in the external fabric. With more stringent building regulations requiring better energy efficiency, airtightness is an increasingly important issue.

天气寒冷的情况下，室内的热空气会通过建筑的围护结构自然地扩散到外面的冷空气中，而同时导致外面的冷空气进入室内，形成气流。这不仅影响了室内环境的舒适性，同时也造成了严重的能量耗散。

低能耗建筑的设计者通常采用气密性措施，减少通过围护结构流失的热量。一个具

有良好气密性的房子的特色元素在于透气膜、多层膜保温、门的挡风帘、三层玻璃等。

暖空气通过房子的外部维护结构泄漏出去，是造成热损失，也就是能源浪费的一个重要因素。提高房屋的气密性，可以减少通过裂缝的自由空气流动。在更为严格的建筑法规提出更高的能源效率要求的情况下，气密性也成为日益重要的话题。

### (6) Wind Cowl Passive Heat Recovery Ventilation System 被动式风帽热回收通风系统

Through air exchange, the Wind Cowl Passive Heat Recovery Ventilation (HRV) System in zero-energy plants ensures high indoor air quality, while minimizing the heat loss.

Typical passive ventilation systems bring fresh air in through the trickle ventilation facilities in the window, and meanwhile discharge exhaust air out of the building by stack effect (the movement of air into and out of buildings driven by buoyancy). For better discharge of the exhaust air, vents are usually installed at the areas of negative wind pressure on the exterior of the building.

The active ventilation system is usually driven by electricity and has exclusive intake pipe and discharge pipe. With the integration of the two pipes, heat recovered from the discharge pipe can be transferred to the fresh air in the intake pipe, thereby reducing the heat loss. The efficiency of the heat recovery system can be as high as 70%. However, the recovered heat is offset by the energy demanded by the electric fan.

The mode of operation of wind cowl in zero-energy plants is similar to that of active ventilation system. Wind cowl system also has exclusive intake pipe, discharge pipe and heat recovery system. The difference lies in the drive of air movement: in the active ventilation system, air is driven by electric fan, while in the zero-energy plant, wind pressure is utilized (positive pressure at the entrance and negative pressure at the exit). The wind cowl in zero-energy plant can still maintain minimum air movement by stack effect even when the external wind pressure is quite low.

工厂中的被动式风帽热回收通风系统通过换气保证较好的室内空气质量，与此同时将热量的损耗降到最低。

典型的被动式通风系统通过窗户上的绢流通风设备将空气引入室内，并利用烟囱效应（烟囱效应是一种利用热空气上浮的原理使空气发生流通的物理现象）引导空气流出室外。因而排风口往往被设置在建筑外部的负风压位置，以便更好地帮助排除室内的废空气。

主动式通风系统通常由电力驱动，并有专用的进气管道和排气管道。可以将这两个管道设置在一起，并通过一个热回收装置将排除空气中的热量传给吸入的新鲜空气，以降低热量的损耗。这种热回收装置的效率通常高达70%。然而，这些重新回收的能量却被驱动电力风扇所需的能量抵消了。

工厂风帽的工作方式与主动通风系统类似，它有专门的进气管道、排气管道和热回